Reprinted from the Journal of the American Medical Association
October 3, 1980, Volume 244

Increased Renal Perfusion and Kidney Size in Convalescent Burn Patients

Cleon W. Goodwin, MD; Louis H. Aulick, PhD;
Richard A. Becker, MD; Douglas W. Wilmore, MD

• **Renal blood flow was elevated in convalescent burn patients shortly before discharge (992±112 mL/min/sq m in burn patients vs 551±37 mL/min/sq m in normal subjects; mean±SE). Autopsy studies demonstrated that renal enlargement was a constant feature of patients after a prolonged hospital course; the kidneys of 28 patients who died after 60 days of hospitalization weighed 241±10 g vs 153±8 g in control subjects. The increase in renal weight was primarily related to cellular hypertrophy and hyperplasia. These physiological and morphological findings in thermally injured patients may be a form of renal work hypertrophy following increased protein catabolism accompanying severe injury.**

(*JAMA* 244:1588-1590, 1980)

FOLLOWING extensive thermal injury and successful resuscitation, cardiac output rises, and this increase is associated in time with an elevation in metabolic rate.[1] The increase in blood flow is related to the size of the burn wound; the cardiac index may reach levels two to three times normal.[2] Although much of the additional circulation is directed to the burn wound, other organs, including the kidneys and liver, increase flow requirements in response to metabolic and physiological demands of extensive injury.[3] We found that increased renal blood flow persists into the convalescent phase of injury, after the burn wound has completely healed, and is associated with striking renal enlargement.

From the US Army Institute of Surgical Research, Brooke Army Medical Center, Fort Sam Houston, Tex. Dr Wilmore is now with the Department of Surgery, Harvard Medical School, Boston.

The views of the authors as expressed herein do not purport to reflect the positions of the Department of the Army or the Department of Defense.

Reprint requests to Library Branch, US Army Institute of Surgical Research, Brooke Army Medical Center, Fort Sam Houston, TX 78234 (Dr Goodwin).

SUBJECTS AND METHODS

Renal Blood Flow Measurements

Renal plasma flow was estimated by the clearance of aminohippurate with the use of the continuous infusion technique.[4] All studies took place in the early morning in well-hydrated, postabsorptive subjects. Two peripheral venous catheters were inserted. An appropriate priming dose of aminohippurate, 3 mg/kg, was given, and a constant infusion of the test solution initiated through one catheter. From experience, infusate concentration and pump speed were selected to maintain venous plasma levels of aminohippurate below 2 mg/dL (usual infusion rate, 10 to 12 mg/min). After at least 30 minutes of constant infusion, the subject emptied his bladder. Serial venous blood samples and carefully timed urine specimens were collected every ten to 15 minutes for three to five consecutive periods. All samples were immediately refrigerated after each collection. After completion of each study, urine and plasma aminohippurate concentrations were measured spectrophotometrically. Mean aminohippurate clearance was then determined and renal blood flow calculated from the measured hematocrit value (mean in controls, 41%; mean in patients, 41%) and by assuming a normal aminohippurate extraction ratio of 0.91. This assumption was confirmed in three selected patients by renal vein catheterization. Body surface area was determined from height and weight. Renal blood flow was expressed in millimeters per minute per square meter of body surface.

Subjects

Renal blood flow was measured in five healthy control subjects (average age, 30 years; range, 20 to 39 years) and in seven convalescing burn patients (average age, 27 years; range, 19 to 49 years). The patients had sustained an average total body surface area burn of 39% (range, 24.5% to 61%) approximately 90 days

(range, 71 to 112 days) before study. All patients were studied just before discharge from the hospital, when their wounds were completely healed and when they were afebrile without evidence of infection or bacteremia over the preceding month.

Autopsy Series

For a 60-consecutive-month period, the autopsy records of patients dying less than 48 hours or more than 60 days after burn injury were examined (autopsy rate, 91% of all deaths).

Student's *t* test for unpaired data was used for statistical analysis.

RESULTS

Renal blood flow in normal subjects was 551±37 mL/min/sq m (mean±SE) and was elevated in the convalescent patients to 992±112 mL/min/sq m ($P<.001$).

The mean kidney weight of 38 patients dying within 48 hours of injury was 153±8 g, well within the weight range of histologically normal kidneys from a large autopsy series.[1] The mean kidney weight of 28 patients dying 60 days or more after burn injury was 241±10 g ($P<.001$). Microscopic examination of kidneys from patients dying early demonstrated vascular congestion, engorgement, and edema in approximately half the patients, and in a few showed early tubular swelling or hemoglobin casts. In patients dying after prolonged hospitalization, the major microscopic features were cellular hypertrophy and hyperplasia. Interstitial edema was not a prominent feature, even in those two patients who had microscopic findings of acute tubular necrosis. No other postinjury renal pathology was noted in the patients dying 60 days or more after injury.

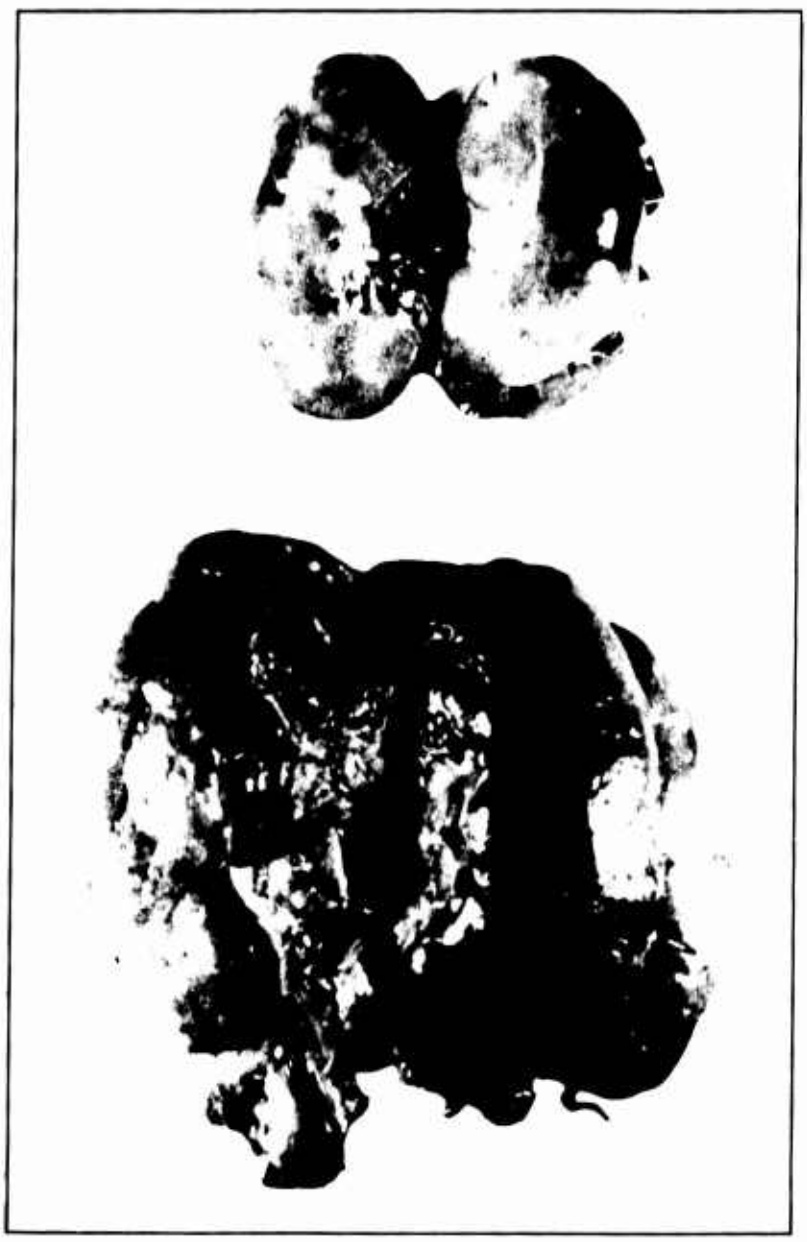
COMMENT

Renal blood flow, measured shortly before hospital discharge, was elevated in healed convalescent burn patients. Our flow studies were conducted over approximately the same postburn period as that covered by the autopsy series. Although not measured in the same patient population, the increased renal blood flow may have been related to the increase in renal mass. Radiological studies in additional convalescent patients have suggested that increased kidney size is a common finding in these persons with an extensive injury and a prolonged hospital course. The increased flow may be required to support the increased renal cell mass in these patients.

The autopsy series in our study demonstrated that increased kidney size occurs in burn patients during the chronic phase of their injuries (Figure). This enlargement, which is characterized by hypertrophy and hyperplasia, was noted not only in patients dying after a prolonged complicated clinical course but also in nearly healed patients who died of the unanticipated complications of acute myocardial infarction and pulmonary embolism. Because of the prolonged and complicated clinical course, two patients demonstrated interstitial edema and tubular necrosis. However, histological examination did not show the presence of amyloid deposits or other infiltrative processes that could account for the increase in renal weight. Thus, the difference in weight between the two groups of patients is most likely due to chronic increases in renal cellular mass induced by large, slow-healing thermal injury.

An increase in renal size has been

Kidneys of patient who died on second day after burn (top; weight, 120 g) compared with those of patient who died 61 days after burn (bottom; weight, 420 g). Photographs were taken from same distance.



associated with a number of pathological processes. It occurs in chronic alcoholics with cirrhosis and fatty metamorphosis of the liver.[6] Renal enlargement is proportional to the extent of liver enlargement in these patients, and the added tissue mass is due to marked cellular hyperplasia and hypertrophy, with enlargement of glomerular diameter. Compensatory growth of the remaining kidney follows unilateral nephrectomy.[7] Although protein and RNA synthesis increases within a day or two of unilateral nephrectomy, visible enlargement requires several weeks. Histologically, the majority of the increase in renal mass is due to hypertrophy, and glomeruli increase in size but not in number. Tubular cells, however, do become hyperplastic and account for approximately one fourth of the increased renal mass. Although subject to species differences, glomerular filtration rate, tubular reabsorption of sodium, and effective renal plasma flow generally increase rapidly after unilateral nephrectomy.

The stimulus for increased renal perfusion and kidney size in convalescent burn patients is not known. Associated with the circulatory and metabolic changes that follow severe thermal burns, glomerular filtration, renal blood flow, and renal oxygen consumption increase two to three times above normal values.[1,8] Hypermetabolism induced by cold stress in certain animal models is accompanied by kidney enlargement.[9] One explanation for this elevated renal mass and perfusion in burn patients is the increased metabolic work required to excrete the large sodium load or end products of protein catabolism. Massive sodium loads, up to 5,000 mEq, are usually required to resuscitate a patient with a large thermal burn. Renal hypertrophy can be produced in experimental animals by prolonged intake of sodium-containing fluid.[10]

The increased caloric support required to maintain body weight and to promote healing of the burn wound may impose additional burdens on the kidneys. Nitrogen excretion may surpass 30 g/day in young adult patients receiving large quantities of dietary nitrogen and carbohydrate. Studies in experimental animals have demonstrated increased renal mass when large quantities of protein were added to the diet.[11] Parenteral nutrition with the infusion of hypertonic glucose, amino acids, and fat emulsion is also associated with increased kidney size.[12] Hyperinsulinemia arising from carbohydrate administration and elevated levels of growth hormone[13] may also be related to the increased renal cell mass in our patients.

Although our patients were maintained on high-calorie, high-protein diets throughout most of their hospitalizations, the total amount of these nutrients gradually decreased as the burn wound was covered and weight gain occurred. Nevertheless, the increased renal blood flow persisted after completion of wound closure, when the patients were receiving normal diets. Since all bloodstream cultures were sterile, elevated renal perfusion was not related to bacteremia or circulating pyrogens, stimuli known to increase renal perfusion.[14]

References

1. Wilmore DW, Long JM, Mason AD Jr, et al: Catecholamines: Mediator of the hypermetabolic response to thermal injury. *Ann Surg* 180:653-669, 1974.
2. Wilmore DW, Aulick LH, Mason AD Jr, et al: Influence of the burn wound on local and systemic responses to injury. *Ann Surg* 186:444-458, 1977.
3. Aulick LH, Wilmore DW, Goodwin CW, et al: Increased visceral blood flow in burn patients, abstracted. *Fed Proc* 38:902, 1979.
4. Nickel JF, Bradley SE: Renal blood flow: I. Extraction and clearance method, in Corcoran AC, Craig LC, Cohn M (eds): *Methods in Medical Research*. New York, Year Book Medical Publishers Inc, 1952, vol 5, pp 147-149.
5. Ludwig J: *Current Methods of Autopsy Practice*. Philadelphia, WB Saunders Co, 1972, p 343.
6. Laube H, Norris HT, Robbins SL: The nephromegaly of chronic alcoholics with liver disease. *Arch Pathol* 84:290-294, 1967.
7. Malt RA: Compensatory growth of the kidney. *N Engl J Med* 280:1446-1459, 1969.
8. Loirat P, Rohan J, Baillet A, et al: Increased glomerular filtration rate in patients with major burns and its effect on the pharmacokinetics of tobramycin. *N Engl J Med* 299:915-919, 1978.
9. Landauer W: Loss of body heat and disease. *Am J Med Sci* 194:667-674, 1937.
10. Goss RJ, Rankin M: Physiological factors affecting compensatory renal hyperplasia in the rat. *J Exp Zool* 145:209-216, 1960.
11. Wilson HEC: An investigation of the cause of renal hypertrophy in rats fed on a high protein diet. *Biochem J* 27:1348-1356, 1933.
12. Cochran ST, Pagani JJ, Barbaric ZL: Nephromegaly in hyperalimentation. *Radiology* 130:603-606, 1979.
13. Wilmore DW, Moylan JA Jr, Bristow BF, et al: Anabolic effects of human growth hormone and high calorie feedings following thermal injury. *Surg Gynecol Obstet* 138:875-884, 1974.
14. Gombos EA, Lee TH, Solinas J, et al: Renal response to pyrogen in normotensive and hypertensive man. *Circulation* 36:555-569, 1967.

Printed and Published in the United States of America